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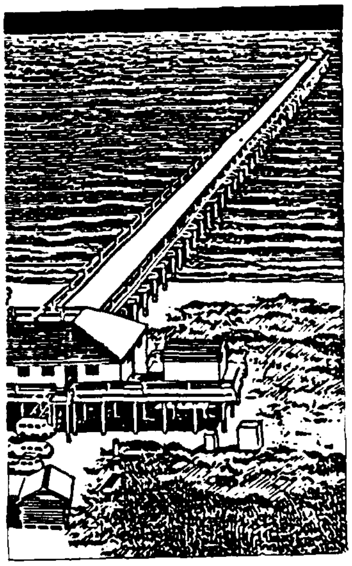

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THE COLONIAL BEACH, VIRGINIA, DETACHED BREAKWATER PROJECT

by

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Coastal Engineering Research Center

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The Colonial Beach, Virginia, segmented detached breakwater and beach fill project consists of two sites, Central and Castlewood Park Beaches, constructed in October 1982 to protect a cohesive bluff (6 to 10 ft in height) eroding at a preproject rate estimated at 1.5 ft/year. The project sites were cooperatively monitored by the US Army Engineer District, Baltimore, and the US Army Engineer Waterways Experiment Station Coastal Engineering Research Center from October 1982 through June 1985. This report presents the data collected during the monitoring program and documents the bathymetric and shoreline response to the structures.

Although the water level increase due to storm conditions was not fully considered in the original design of the beach fills, the project sites have successfully prevented erosion of the beach bluff. Results from the monitoring program were used to modify the (Continued)

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19. ABSTRACT (Continued).

Central Beach fill elevation, eliminating inundation of the beach during storms and increasing its recreational value. Volumetric analyses indicated that the Central Beach project area lost material during the most recent time period; however, the region which lost the least amount of sediment was to the lee of the structures. The Castlewood Park Beach area gained nearly the same amount of material that the Central Beach area lost; however, 90 percent of this gain was in the offshore region. The Central Beach project performing successfully in retaining the original quantity of beach fill, and Castlewood Park Beach has accreted additional material. However, the Castlewood Park Beach area has limited recreational appeal due to the marshy tidal flat and vegetative growth in the area. Both project sites are performing as designed, in protecting the back beach, bluff, and road, and in preventing project-induced shoaling of the Monroe Creek Federal Navigation Channel.

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PREFACE

The study summarized in this report was authorized by the Headquarters, US Army Corps of Engineers, and performed as part of the Civil Works Research and Development Work Unit 31232, Evaluation of Navigation and Shore Protection Structures. Mr. John H. Lockhart, Jr., was Technical Monitor. Funds were provided through the Coastal Structures and Evaluation Branch, Coastal Engineering Research Center (CERC), at the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. Data presented in the report were collected by the Coastal Engineering Section of the US Army Engineer District, Baltimore (NAB). Mr. Edward Fulford, NAB, was the District point of contact and provided valuable assistance throughout the course of this study.

This report was prepared by Ms. Julie D. Rosati, Hydraulic Engineer, and Ms. Joan Pope, Chief, Coastal Structures and Evaluation Branch (CS&E). Dr. Clifford L. Truitt, Research Hydraulic Engineer, CS&E, was Principal Investigator of the work unit. Mr. Darryl Bishop, CS&E, provided drafting support for the figures in the report. This report was edited by Mrs. Nancy J. Johnson, Information Products Division, under the Intergovernmental Personnel Act.

Work was performed under the direct supervision of Ms. Pope, Chief, CS&E; Mr. Thomas W. Richardson, Chief, Engineering Development Division; Dr. Charles L. Vincent, Program Manager, CERC; Mr. Charles C. Calhoun, Jr., Assistant Chief; and Dr. James R. Houston, Chief, CERC.

COL Dwayne G. Lee, EN, is Commander and Director of WES. Dr. Robert W. Whalin is Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic yards	0.76545549	cubic metres
degrees (angle)	0.01745329	radians
feet	0.3048	metres
miles (US statute)	1.609347	kilometres
pounds (mass)	0.4535924	kilograms

THE COLONIAL BEACH, VIRGINIA, DETACHED BREAKWATER PROJECT

PART I: INTRODUCTION

1. The Colonial Beach, Virginia, segmented detached breakwater and beach fill project is located on the west side of the Potomac River estuary, approximately 69 miles* downstream from Washington, DC, and 40 miles upstream from the mouth of the Potomac River (Figure 1). The project consists of two sites constructed in October 1982 to protect a cohesive bluff (6 to 10 ft in height) eroding at a preproject rate estimated at 1.5 ft/year (US Army Engineer District (USAED), Baltimore, 1980). The northernmost project, Central Beach, consists of a four-segment detached breakwater and beach fill; Castlewood Park Beach, approximately 2.9 miles south of Central Beach, consists of a three-segment detached breakwater, beach fill, and terminal groin (Figure 2). Both sites experience river and tidal currents, water-level changes, and fetch-limited wind waves.

2. Both project sites were cooperatively monitored by the USAED, Baltimore, and the US Army Engineer Waterways Experiment Station Coastal Engineering Research Center (CERC) from October 1982 through June 1985. Data collected include aerial photography, bathymetric and topographic surveys, wave-gage data, littoral environment observation (LEO) data, and observations made during several site inspections, which include a qualitative current pattern study and limited sediment sampling. This report documents the general performance of the project sites and extends results from the monitoring program presented in a preliminary report (Dean, Pope, and Fulford 1986) to take advantage of additional data and improved analytical techniques.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 5.

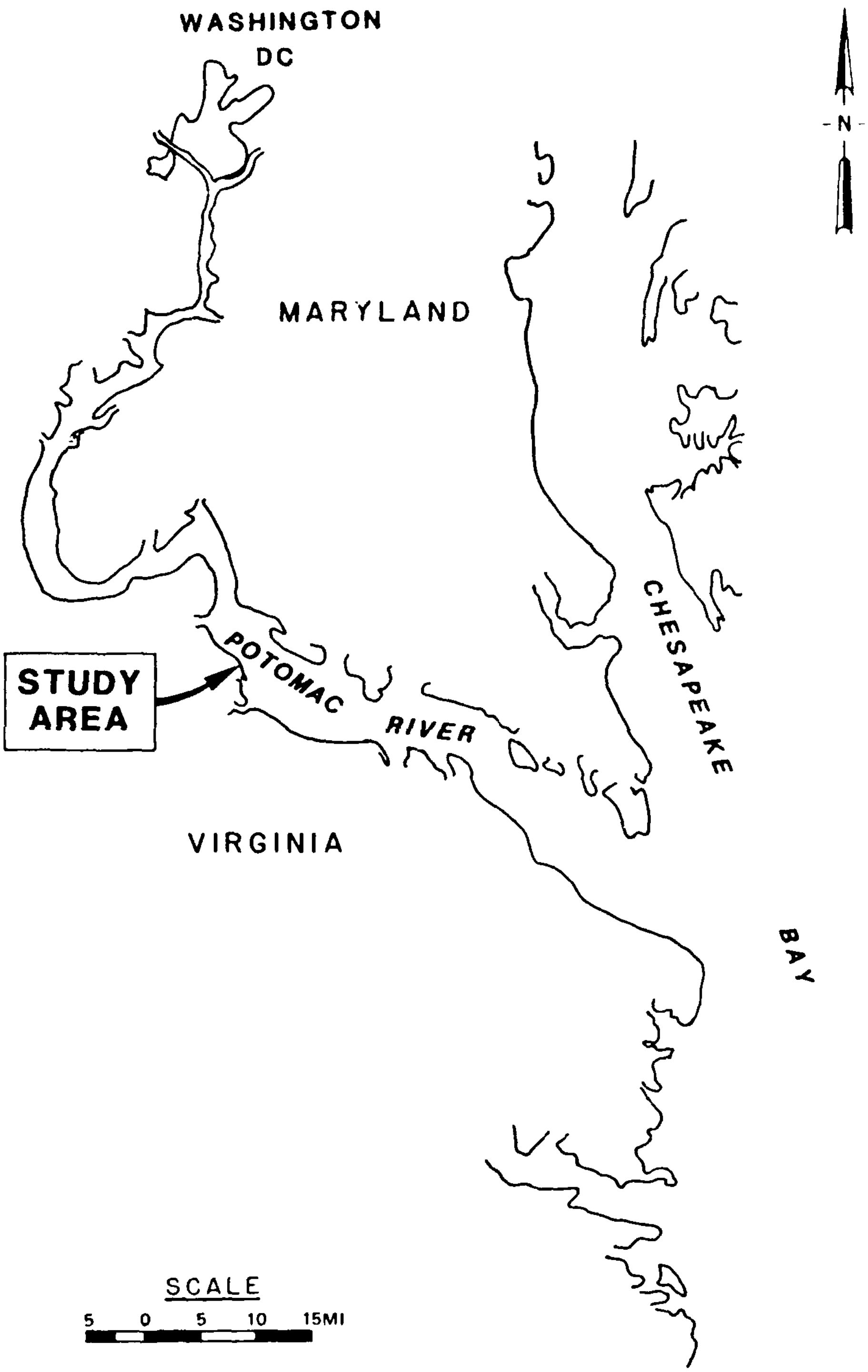

Figure 1. Colonial Beach study area location

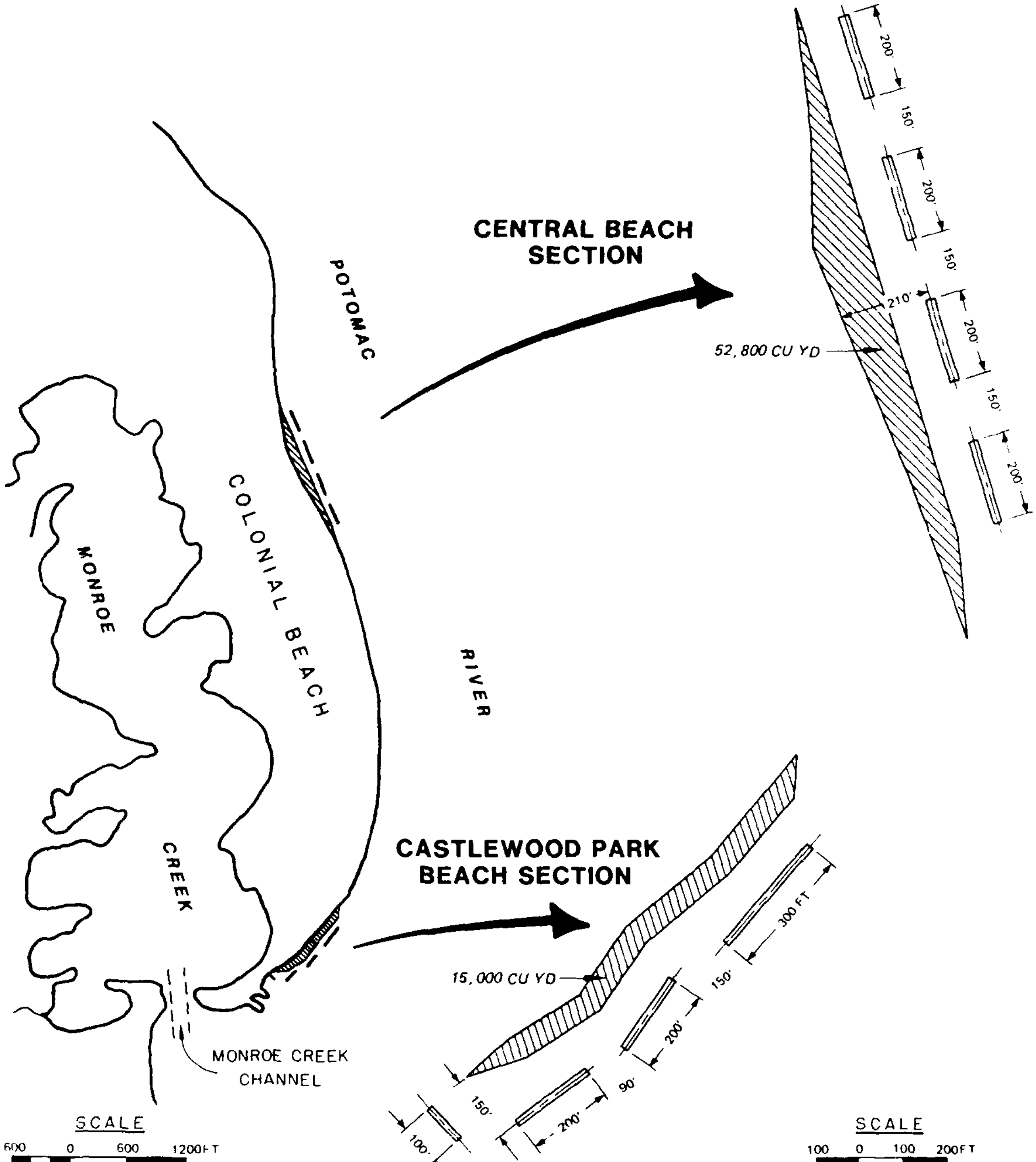

Figure 2. Colonial Beach Peninsula, location of project areas and site parameters

PART II: BACKGROUND

3. Colonial Beach is located on the west side of the Potomac River, one of the five primary rivers contributing freshwater inflow to Chesapeake Bay (Figure 1). The town of Colonial Beach occupies a low peninsula approximately 2.5 miles in length. The Potomac River is approximately 3 to 4 miles wide opposite Colonial Beach and is affected by a semidiurnal tide with mean range of 1.6 ft and a spring range of 1.8 ft.

4. The southwest shore of the Potomac River is characterized by nonexistent to medium width beaches (0 to 15 ft wide) and low banks and bluffs ranging from 15 to 20 ft in height. The soils and bluffs of the area are principally composed of Pleistocene marine and fluvial deposits which make up the Talbot terrace. The Talbot terrace was formed by a reworking of the older Coastal Plain formations by the Talbot Sea and its tributaries. These deposits consist primarily of clay loam and sand but also contain gravel, clay, marl, peat, and some boulders. The Talbot contains less coarse materials than do the other Pleistocene formations, and the material is easily eroded (US Congress*). Before the Colonial Beach project was built, it was estimated that of the 2.5 miles of Colonial Beach shoreline, 2 miles were eroding at a rate of 1.5 ft/year (USAED, Baltimore, 1980).

5. The shore fronting Colonial Beach is protected by many types of coastal construction such as concrete and asphalt revetments, concrete-filled nylon bag groins, timber groins, gabion basket revetment, treated timber seawalls, dumped concrete slabs, and rubble and backfill. Although these forms of shore protection have historically reduced local bluff erosion rates, the recreational beach has gradually disappeared.

6. Colonial Beach, because it has a limited open water fetch distance (ranging from 3 to 18 miles), is typically characterized by a mild wave climate with small, short period waves (0 to 1 ft, 2 to 3 sec). There are periodic (five or six times per year) local storm events with wave heights and periods estimated from hindcasting techniques ranging from 1.5 to 4.5 ft and 2.3 to 4.5 sec, respectively (USAED, Baltimore, 1980). During normal periods of low energy wave action, littoral drift is nearly nonexistent. The storm

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* US Congress (81st), First Session, Document No. 333. 1949. "Colonial Beach, Va., Beach Erosion Control Study," Letter from the Secretary of the Army, Committee on Public Works, Washington, DC.

waves, which are able to move sediment, are particularly significant when they occur simultaneously with high river flows and increased water levels resulting from low-pressure barometric systems.

7. A typical preproject beach area approximately 5 to 15 ft wide is readily inundated with an increase in water level. Steep storm waves can then reach the 5- to 10-ft-high bank section behind the beach. Wave action undermines the bank, eventually causing it to slump. Continued wave action sorts and winnows out the silts and clays, which comprise most of the bank material, leaving small quantities of sand and gravel behind. The winnowed material is transported offshore and downstream by a combined tidal and fluvial current regime (USAED, Baltimore, 1980). In areas of unrestricted fetch such as the Atlantic Ocean, low steepness swell waves occur after storms. These waves would tend to transport material onshore and rebuild the beach. However, Colonial Beach does not experience these long period, beach constructive swell waves.

8. Because of the low to nonexistent longshore sediment transport rate in the area and the tendency for steep waves, groin systems at Colonial Beach are not effective in building and retaining a beach. Any littoral material trapped by the Colonial Beach groins appears to be lost during storm events. The concrete and asphalt revetments and the seawalls which front the area protect the bank for awhile, but they do little to dissipate wave energy and can even accentuate high runup during storms. Both forms of protection exhibit toe scour and soil erosion at the crest due to wave overtopping, resulting in damage to the roadway and other facilities at the top of the protection.

9. Prior to construction of the projects, the Colonial Beach shore road had gained a reputation as the most expensive roadway in Virginia to maintain (USAED, Baltimore, 1980). In addition, shoaling in the Federal Navigation Channel (Monroe Creek Channel) at each end of the Colonial Beach Peninsula (Figure 2) was a continual problem; shoaling rates were estimated at 1,500 cu yd/year (USAED, Baltimore, 1980).

PART III: DESIGN OF THE PROJECT

10. Goals of the project were to: (a) reduce erosion at Central and Castlewood Park Beaches, thereby protecting the backshore bluff and road; and (b) provide additional recreational beach at these areas. In addition, the project was to be designed such that any type of project beach fill would not increase shoaling in the Monroe Creek Federal Navigation Channel.

11. The alternative solutions considered to fulfill these goals were: a groin system, beach fill, and a breakwater system. Existing timber and nylon grout-filled bag groins at the site had proven ineffective. Even with the placement of beach fill, it was unlikely that a groin field could retain the sediment for very long considering the steep wave climate. Beach fill was rejected because the inland borrow material was finer than the Castlewood Park Beach native material, and, without protection, this sediment would soon be transported offshore and possibly result in additional shoaling in Monroe Creek Channel.

12. Approximately 6 miles downriver from Colonial Beach, at Westmoreland State Park, 6,000 cu yd of borrow material from the same source as proposed for Colonial Beach had been placed and lost completely within a 6-month period (USAED, Baltimore, 1980). Colonial Beach, due to its proximity to Westmoreland State Park and its shoreline orientation, is subjected to similar sediment transport conditions. A breakwater system without beach fill would take some time to trap enough sand to create a recreational beach due to the small amount of littoral material. In addition, adjacent shores would likely experience increased erosion. Headland and detached breakwater systems with beach fill were considered for both locations. In the design analysis, detached breakwaters with beach fill were determined to have a more favorable benefit-to-cost ratio than headland breakwaters with beach fill and were therefore the selected alternative. The detached breakwater systems with beack fill would reduce wave-induced sand transport, both alongshore and offshore.

13. The Colonial Beach project was designed by USAED, Baltimore. Thirty years of recorded wind data from Dahlgren Air Base (approximately 10 miles north of Colonial Beach) were used to hindcast a shallow-water design wave. The greatest wave height produced in the Potomac River near Colonial Beach was computed at 4.5 ft (USAED, Baltimore, 1980). The design water depth

for construction of the breakwater segments was detrmined using the shallow-water depth system as defined by Toyoshima (1972), and indicated that construction of the breakwaters should be in water depths of 3 ft or less; the segment length and spacing were developed using design information for the Lakeview Park project in Lorain, Ohio. designed by the USAED, Buffalo (USAED, Baltimore, 1980).

Structure Planform

14. The four-segment detached breakwater at Central Beach, the northernmost project, has segments approximately 200 ft in length with 150-ft gaps between segments. The Castlewood Park project has one breakwater segment of 300 ft in length, and two segments of 200 ft in length, with 150- and 90-ft gaps, respectively, between segments. Castlewood Park Beach also has a 100-ft terminal groin at its southern end to prevent loss of project beach fill into the Monroe Creek Navigation Channel located south of the peninsula. All breakwater segments were oriented perpendicular to the design wave direction (Figure 2).

Beach-Fill Design

15. Based on analysis of the existing beach profiles in the area, the beach-fill slope above mean low water (mlw) was designed from 1 on 20 to 1 on 15. The berm height of the beach fill was designed at +3 ft mlw, the historical berm height in the area. The width of the beach fill area above mean high water (mhw) was designed from 60 to 120 ft to provide enough beach area to meet recreational beach demands. Fill material was to be placed offshore in order that the toe of the beach fill was in line with the structures (USAED, Baltimore, 1980). Central Beach initially had 52,800 cu yd of beach fill placed, with a renourishment in October 1984 of 3,000 cu yd. The initial quantity of material placed at Castlewood Park Beach was 15,000 cu yd. The design median grain size for the beach fill was 0.5 mm; native beach material median grain sizes for Central and Castlewood Park Beaches were 0.8 and 0.3 mm, respectively. Beach fill at both locations was trucked in from a commercial sand and gravel pit located approximately 5 miles from Colonial Beach, then graded by construction vehicles.

Structure Cross-Sectional Design

16. The breakwaters at both locations were overbuilt to an elevation of +3.0 ft mlw to allow for 1.0-ft settlement. All structures had a design crest width of 6.0 ft and side slopes of 1.5H on 1.0V. The breakwater design depth was 2.0 ft mlw. Although the maximum hindcast wave for Colonial Beach was computed at 4.5 ft, the structures were designed for a deepwater design wave height of 6.0 ft resulting in a 2,000-lb stone armor layer and 500-lb stone underlayer. The foundations for the breakwater segments included stone bedding layer 1 ft thick, extending 5 ft beyond the armor stone toe; filter fabric blanket was also placed at Castlewood Park. All stones for the structures were placed from the beach fill with a crane.

PART IV: MONITORING PROGRAM

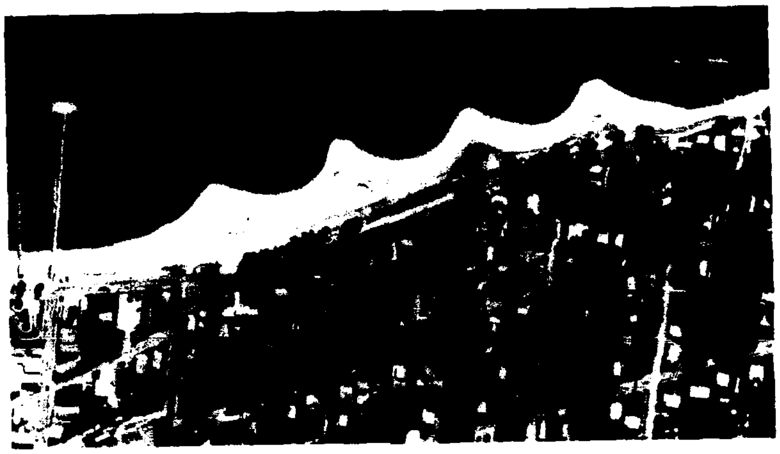
17. Monitoring of the Colonial Beach project sites was conducted to document and to evaluate performance of the two breakwater systems. Data collected during monitoring included aerial photography (photographed with survey controls: June 1984 and February 1985; photographed without survey controls: March 1983), wave-gage data (October 1984 through January 1985), observations made during several site inspections, which included a qualitative current pattern study and limited sediment sampling (October 1984 and August 1985), preconstruction and postconstruction surveys (February 1981; November 1983 and March 1984), and LEO data (intermittently from March to December1985). Because the LEO and sediment sampling data were so limited in scope, these data sets will not be discussed in this report.

Aerial Photography

18. Central Beach aerial photographs are presented in Figure 3, and Castlewood Park Beach aerials are included in Figure 4. The darker zones toward the back beach of both sites in the photographs consisted of finer sized sediment, and the zones occasionally were filled with water and vegetation. Originally the beach fill was built to +3 ft mlw, but on occasions when an extra-tropical low barometric pressure system (i.e., a water level setup and storm waves) occurred simultaneously with an astronomical high tide, the back beach areas became inundated. The waves were able to break on the reveted and nonreveted banks, resulting in scouring at the base of the revetment and bluff erosion. A sinuous beach berm formed, mirroring the diffraction pattern of the breakwater. When the water level returned to normal, water was ponded in the back beach area leaving the sinuous berm as a narrow beach offshore (Figure 5).

19. The back beach depression apparent in the March 1983 aerials (Figures 3a and 4a) had become more pronounced by November 1983 (Figure 6). In October 1984, 3,000 cu yd of beach fill with a median grain size of 0.5 mm was placed in the low back beach region at Central Beach, raising the entire beach elevation to +4.0 ft mlw.

a. Uncontrolled vertical, March 1983



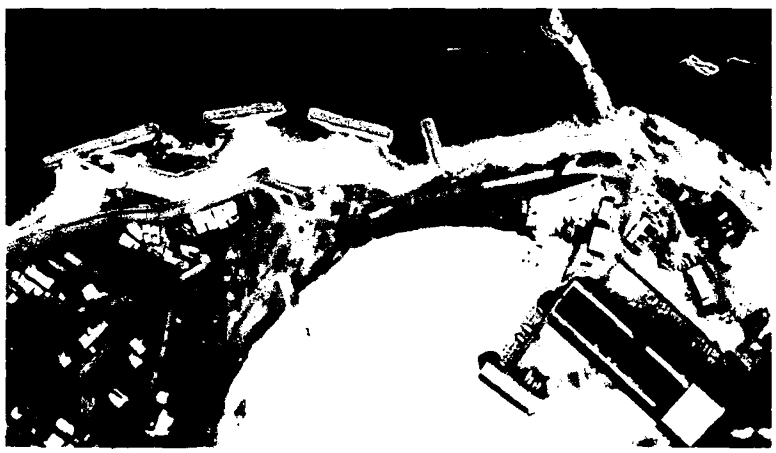
b. Controlled vertical, June 1984

c. Controlled vertical, February 1985

Figure 3. Central Beach aerial photographs

a. Uncontrolled vertical, March 1983

b. Controlled vertical, June 1984



c. Controlled vertical, February 1985

Figure 4. Castlewood Park Beach aerial photographs

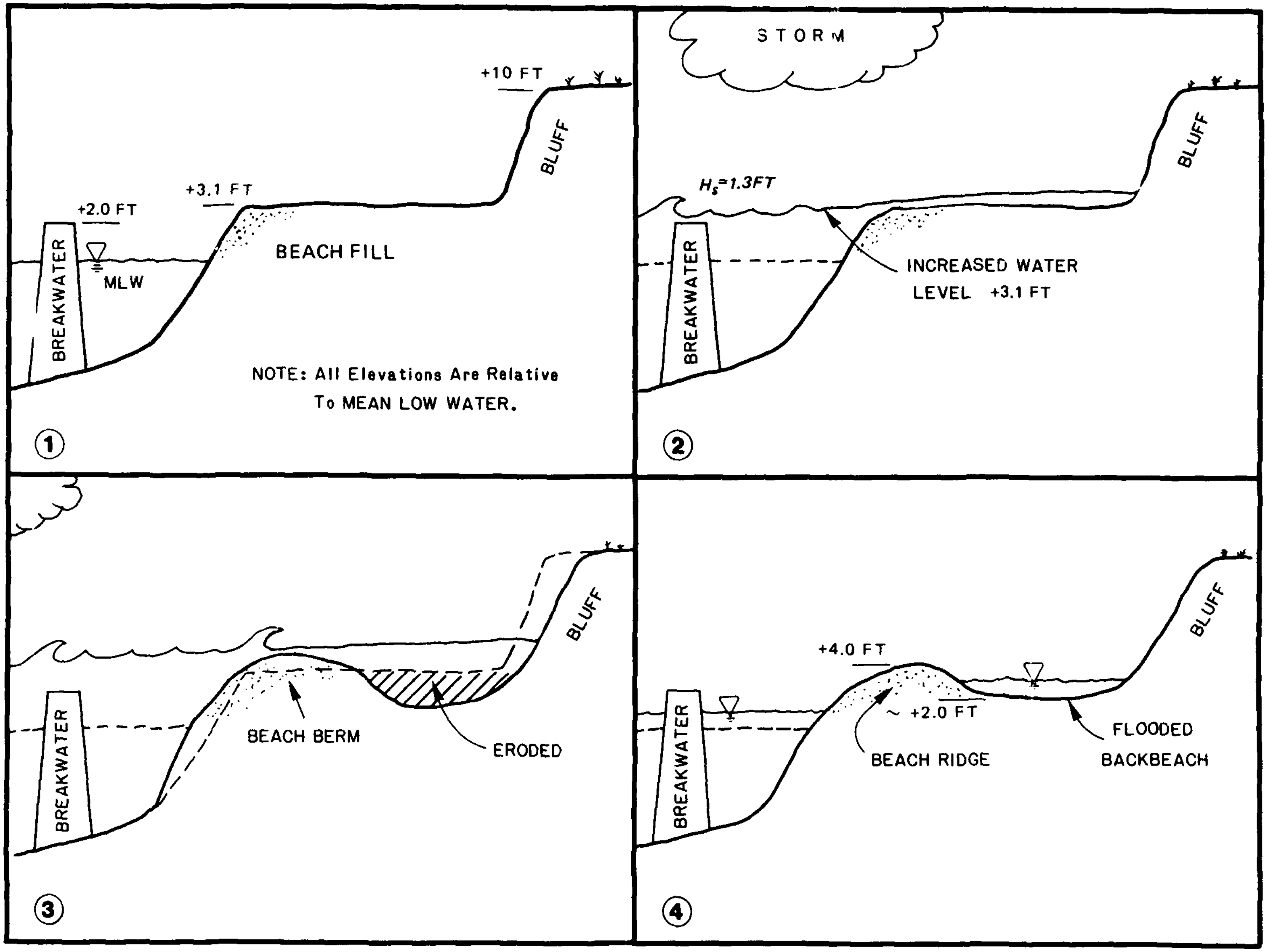


Figure 5. Buildup of project area beach ridge through a storm cycle

a. Central Beach

b. Castlewood Park Beach

Figure 6. Low back beach areas filled with water, September 1983

Wave-Gage Data

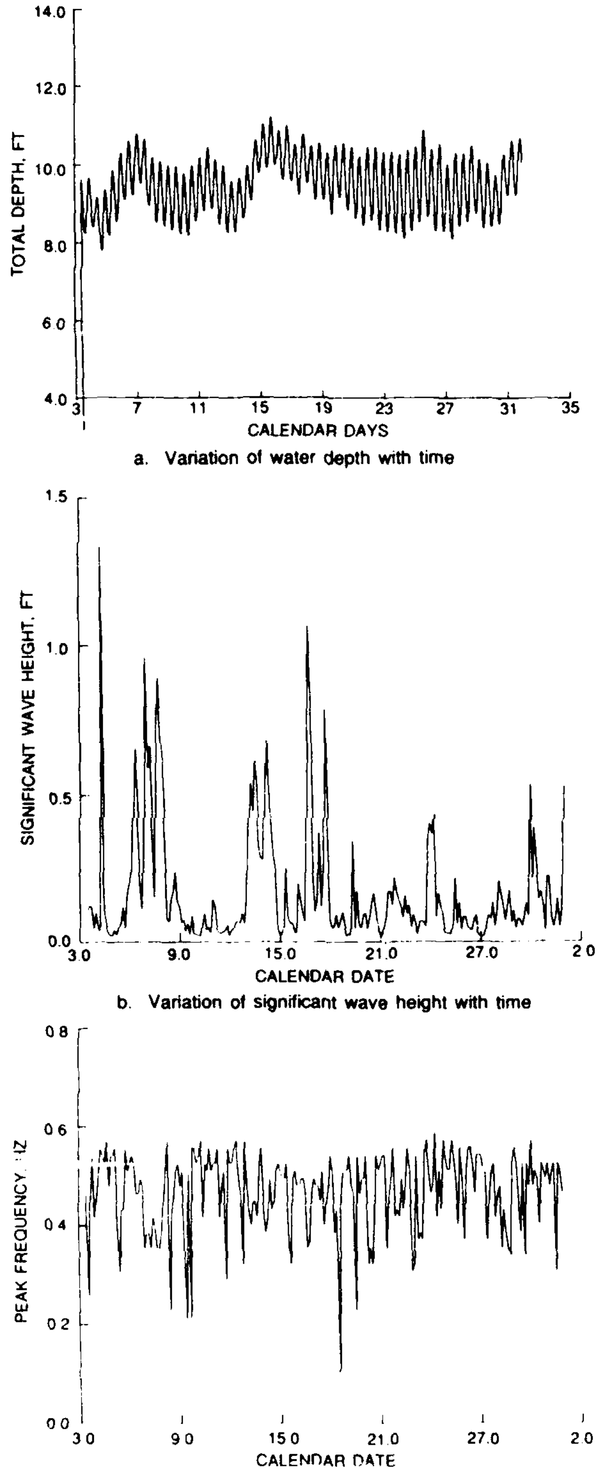
20. A Sea-Data 635-11 wave gage and temperature depth recorder were installed in approximately 8 ft of water off Central Beach in October 1984. The gage was serviced in mid-December 1984, and was in place until early January 1985 when an ice jam dislodged the timber piling on which the instruments had been mounted. Wave-height and water-level data sets were combined to compute the possible frequency for inundation of the placed beach (Figure 7).

21. During the 3-month period of water-level and wave-height data collection, the initial +3 ft mlw beach fill would have been inundated between 5 and 37 times. An exact number of inundation events cannot be calculated because of a 0.5-ft uncertainty in the depth of gage placement. Significant storm waves recorded during the data collection period were approximately 1.3 ft in height. The highest possible wave, using shallow-water wave hindcasting techniques, occurs from east-east southeast, the major storm direction and longest fetch distance (96,500 ft). Such a wave would be produced by a sustained wind speed of 45 mph from east-east southeast and would have a deepwater significant wave height of 4.5 ft and a significant period of 4.6 sec (USAED, Baltimore, 1980).

22. Figure 8 presents the Potomac River average monthly flows for the period 1930-1982. The dashed lines represent the average flows for each month of 1984 during which wave data were collected. Flows experienced during the wave data collection period are either average or below average flows. Storm-induced inundation of the original +3.0 ft mlw beach fill during high flow spring months would be certain.

Site Inspections

23. A qualitative current pattern assessment was performed in October 1984. The wave height at the time was 1.0 ft, the period was 2.3 sec, and the wave direction was from the northeast (approximately 35 deg left of shore-normal). Fluorescence dye packets were placed in the water on the north sides of the salients at Central Beach, and the dispersion of dye through time was observed (Figure 9). Castlewood Park Beach was sheltered from northeast waves; therefore, conditions were calm and a current pattern study was not performed at the site.



a. Variation of water depth with time

b. Variation of significant wave height with time

c. Variation of peak frequency with time

Figure 7. Wave-height and water-level data sets, October 1984

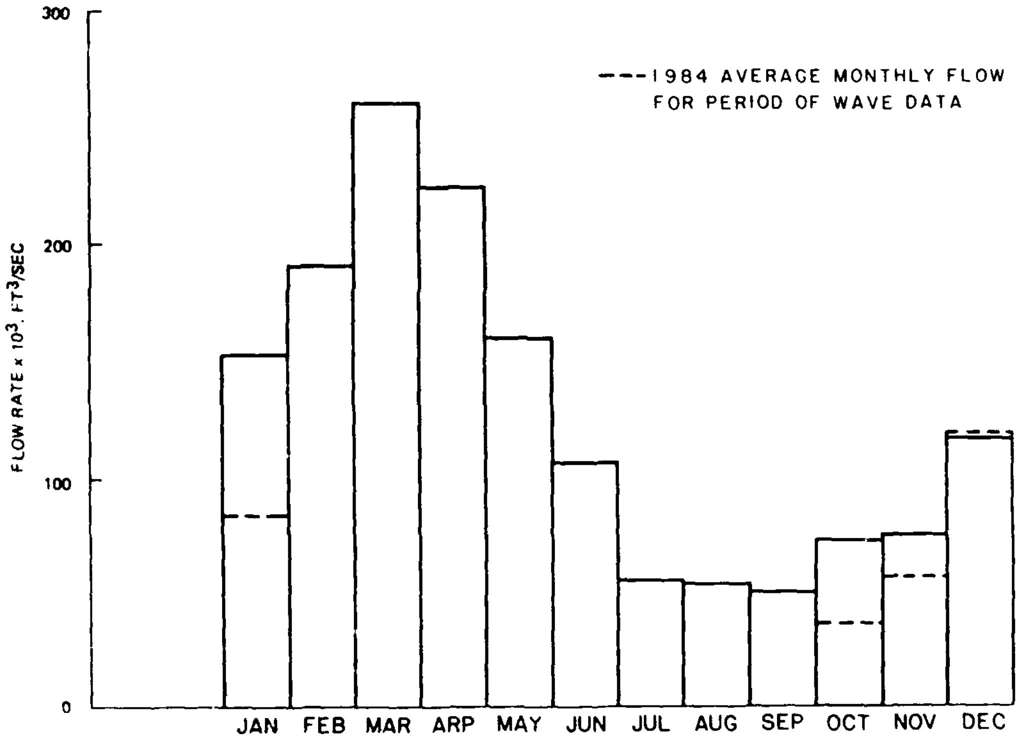


Figure 8. Average monthly Potomac River flow (ft/sec) at Chain Bridge Station (near Washington, DC) and 1984 average monthly flow for period of wave data (dashed lines)

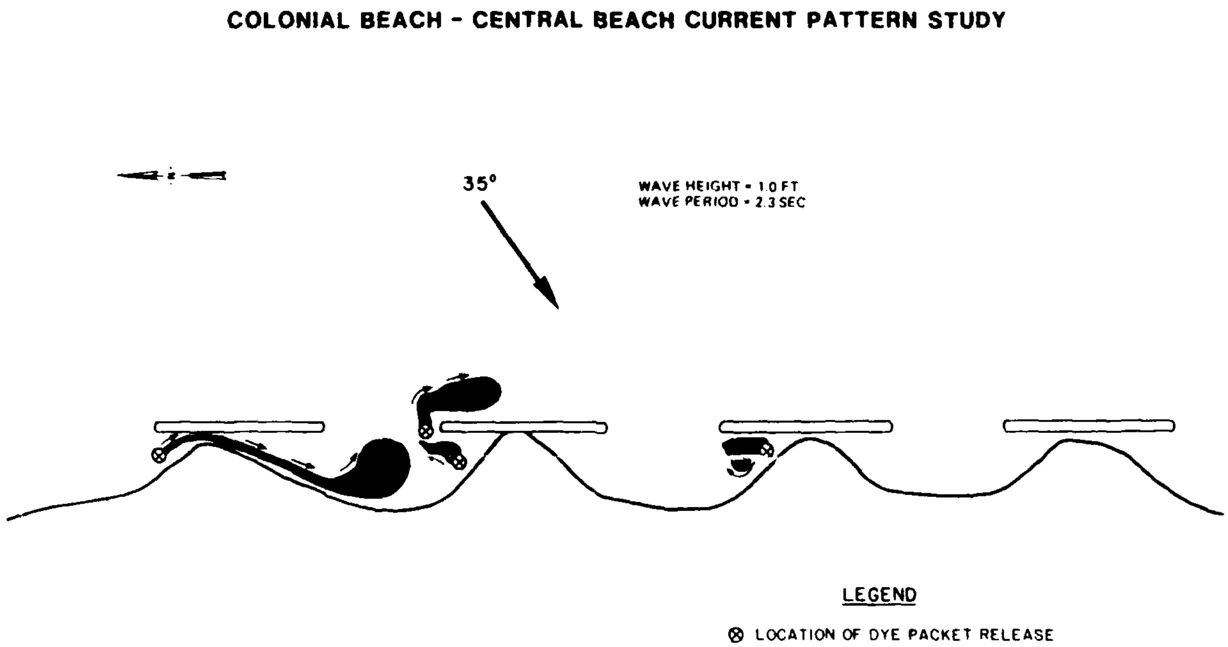


Figure 9. Central Beach current pattern study, October 1984

24. When a tombolo (beach salient connected to the structure) exists, current moves seaward of the breakwater (Figure 9). The tombolo-breakwater combination functions as a groin, deflecting the current offshore of the breakwater segment. The deflection of current riverward when a tombolo exists suggests that longshore movement of sediment through the beach system has been stopped. When an unconnected salient is present, the littoral current continues to flow landward of the breakwater (Figure 9).

25. Another site inspection was conducted in August 1986, after beachfill placement at Central Beach. Although only Central Beach received additional beach fill, neither area appeared to have the major back beach flooding problems which were apparent earlier. However, several overwash depressions were observed in all but the northernmost salient at Central Beach. These depressions were probably created during a water level setup in the gaps between the tombolos and near-tombolos. The salient in the lee of the northernmost structure at Central Beach was noted to have eroded to the degree that small bedding stone was exposed. No subaerial beach was observed in the unprotected area south of Central Beach. The gap between the northernmost and middle segments at Castlewood Park Beach was observed to be an organic-rich, marshy, protected tidal flat. A double-ridged tombolo existed in the lee of the northern segment, and a single tombolo existed behind the middle segment. The double ridged tombolo was heavily vegetated.

Bathymetric Data

26. Contour plots of the topographic and bathymetric surveys (Figures 10-15) were generated from Central and Castlewood Park Beach survey data using a contour-plotting software package* (Hansen, in preparation). The featureless narrow shoreline at both sites prior to project construction evolved into a wider, sinuous beach in later time periods due to placement of beach fill and protection from the segmented detached breakwaters. Tombolos are apparent at the second segment from the north at Central Beach and northernmost segment at Castlewood Park Beach in all postproject time periods.

27. Elevation difference plots were also prepared to show the change in contours from February 1981 to November 1983 and from November 1983 to

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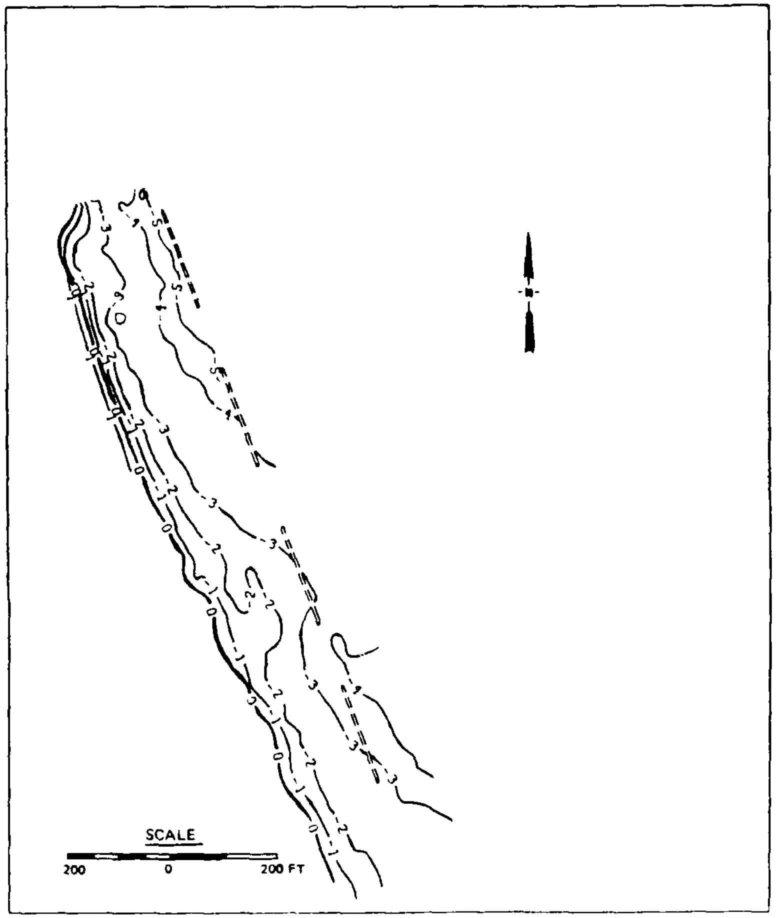

Figure 10. Central Beach February 1981 contour plot (in feet relative to mlw) (prior to project construction)

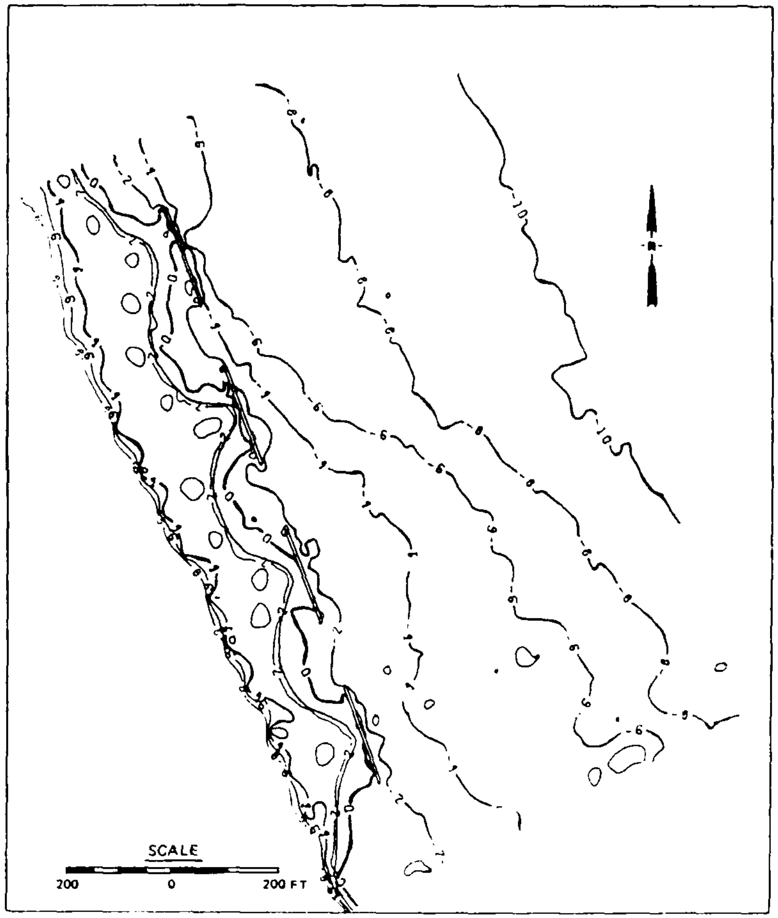

Figure 11. Central Beach November 1983 contour plot (in feet relative to mlw)

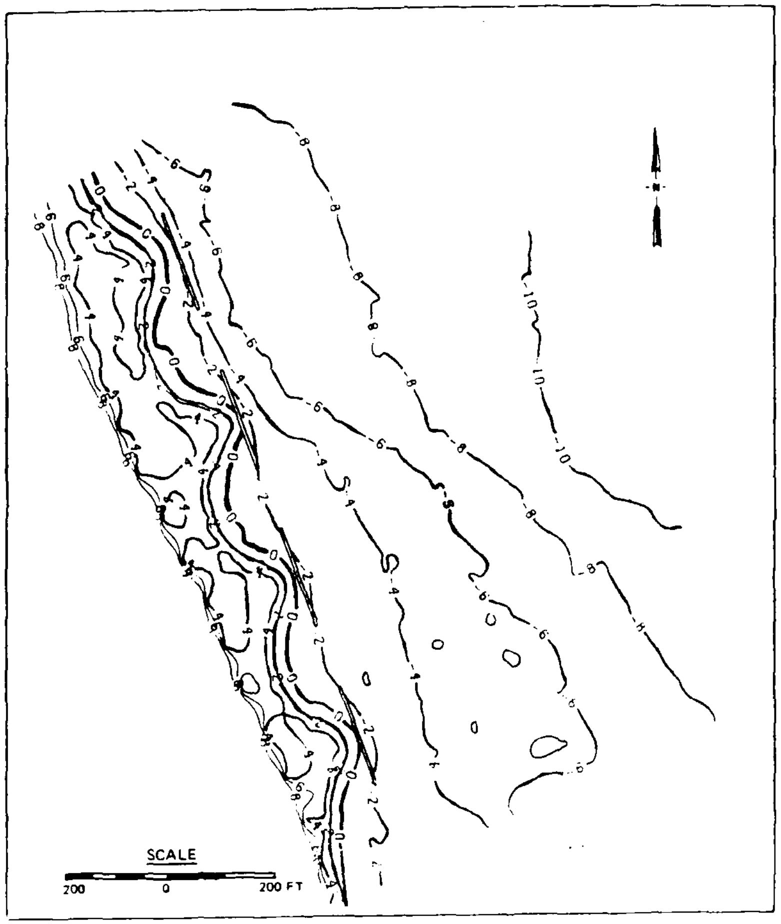

Figure 12. Central Beach March 1984 contour plot (in feet relative to mlw)

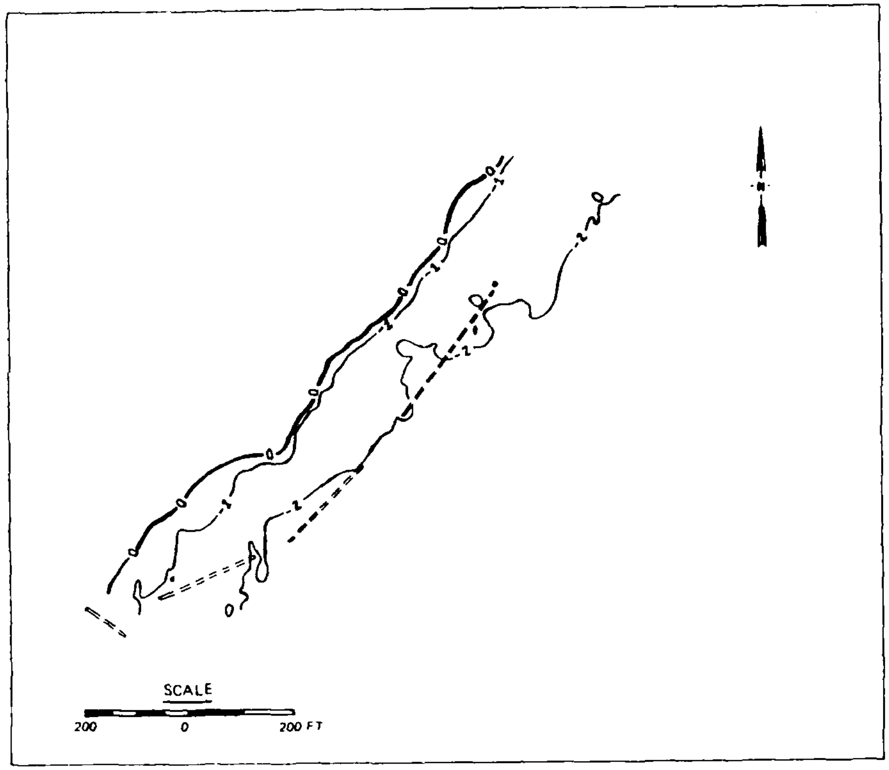

Figure 13. Castlewood Park Beach February 1981 contour plot (in feet relative to mlw) (prior to project construction)

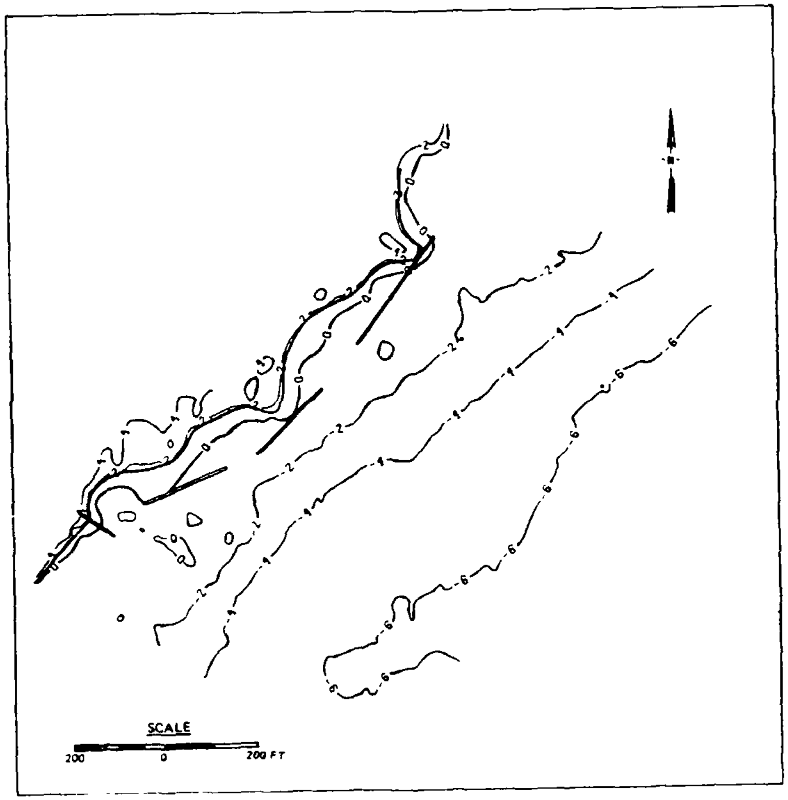

Figure 14. Castlewood Park Beach November 1983 contour plot (in feet relative to mlw)

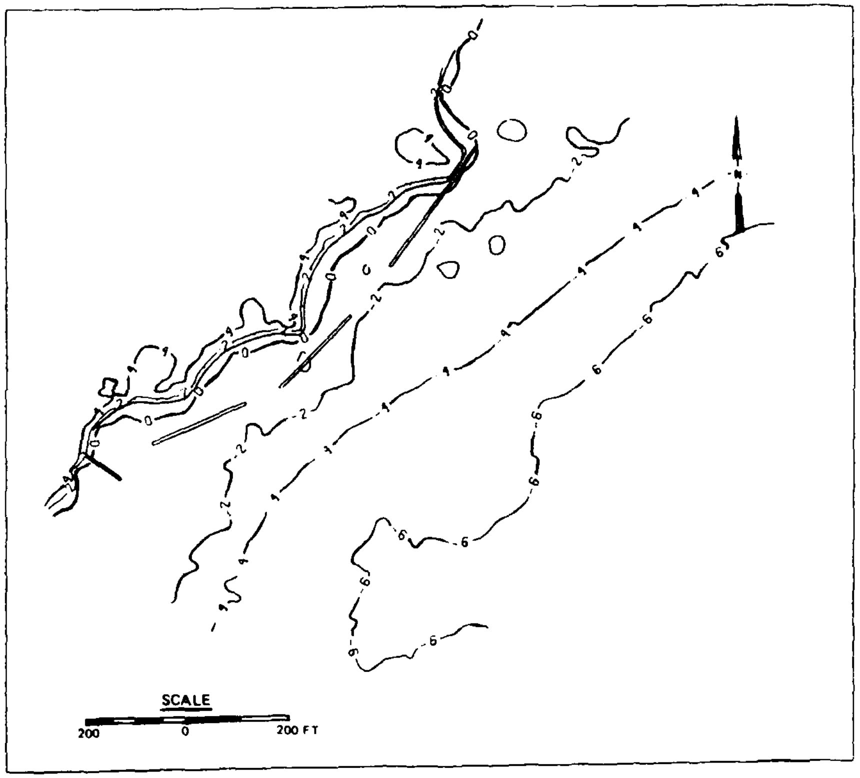

Figure 15. Castlewood Park Beach March 1984 contour plot (in feet relative to mlw)

March 1984 (Figures 16-19). Integration of the contour change plots resulted in the volume of sediment increase/decrease for each time period at each project site and for each region defined in Figures 20 and 21 (Table 1). Regions were defined as such to calculate volume changes for (a) areas that the structures protected (leeward of breakwater), (b) areas in which the structures might induce scour or erosion (offshore of breakwater and downdrift of groin), and (c) areas that should be relatively unaffected by the structures (offshore).

28. From February 1981 to November 1983, Central Beach had a volume increase of 61,300 cu yd, and Castlewood Park had an increase of 21,200 cu yd. Subtracting the quantities of beach fill placed during the period, Central Beach accreted 8,500 cu yd, or 3,100 cu yd/year, and Castlewood Park Beach accreted 6,200 cu yd, or 2,300 cu yd/year of sediment. From November 1983 to March 1984, Central Beach lost approximately 10,200 cu yd of material and Castlewood Park Beach gained approximately the same quantity. Although the equal loss and gain of material between sites might suggest that material moving from Central Beach may be deposited in the Castlewood Park Beach area, the 2.9-mile distance between these sites indicates that a direct exchange of material is unlikely.

29. Using the data in Table 1, the volume changes for each region were normalized using the area of the region. Volume changes for each region as defined in Figures 20 and 21 are presented in Table 2.

30. The data show the large increase in volume per unit area for both sites in the area lee of the structures during the first time period due to the placement of beach fill. The areas offshore of the breakwaters also gained some material during this period. From November 1983 to March 1984, all Central Beach regions lost material; however, the area leeward of the structures lost the least volume per unit area. The "leeward of breakwater" area at Castlewood Park Beach essentially remained the same during this second time period, while the offshore areas accreted slightly. Ninety percent of the 10,220 cu yd of material gained at Castlewood Park Beach during this time period was gained offshore of the structures. Obviously, this volume gain at Castlewood Park Beach was due to fluvial and/or tidal processes rather than protection from the breakwater. The area downdrift of the groin gained some material, indicating that either some transport from the south to the north occurs occasionally, or that material from the sheltered region behind the structures can bypass the 100-ft-length groin.

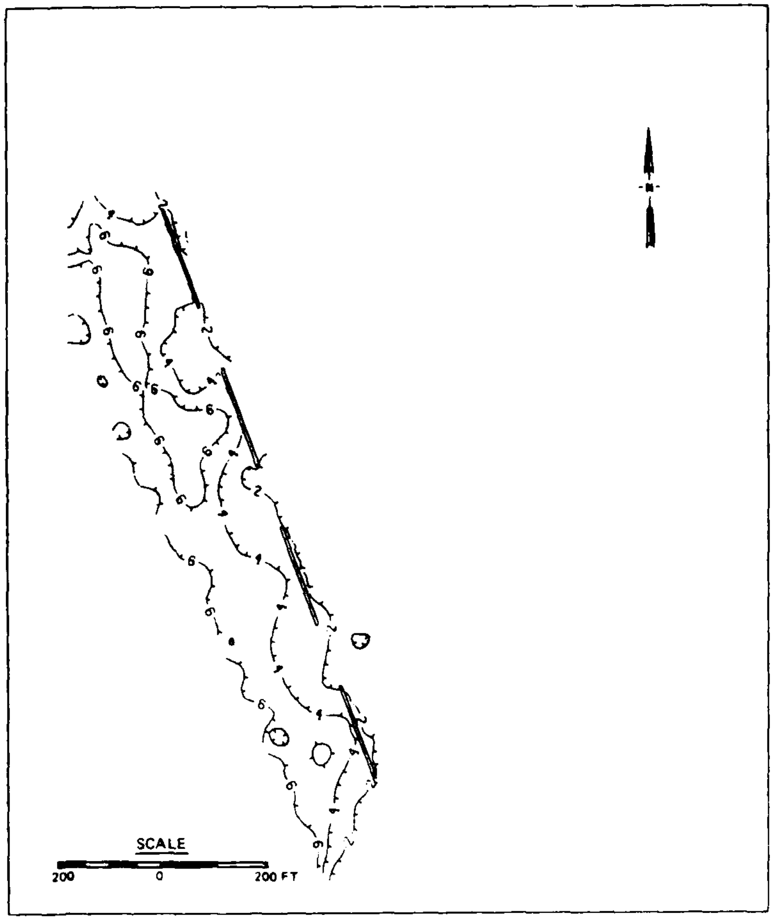

Figure 16. Central Beach February 1981 to November 1983 difference plot (in feet)

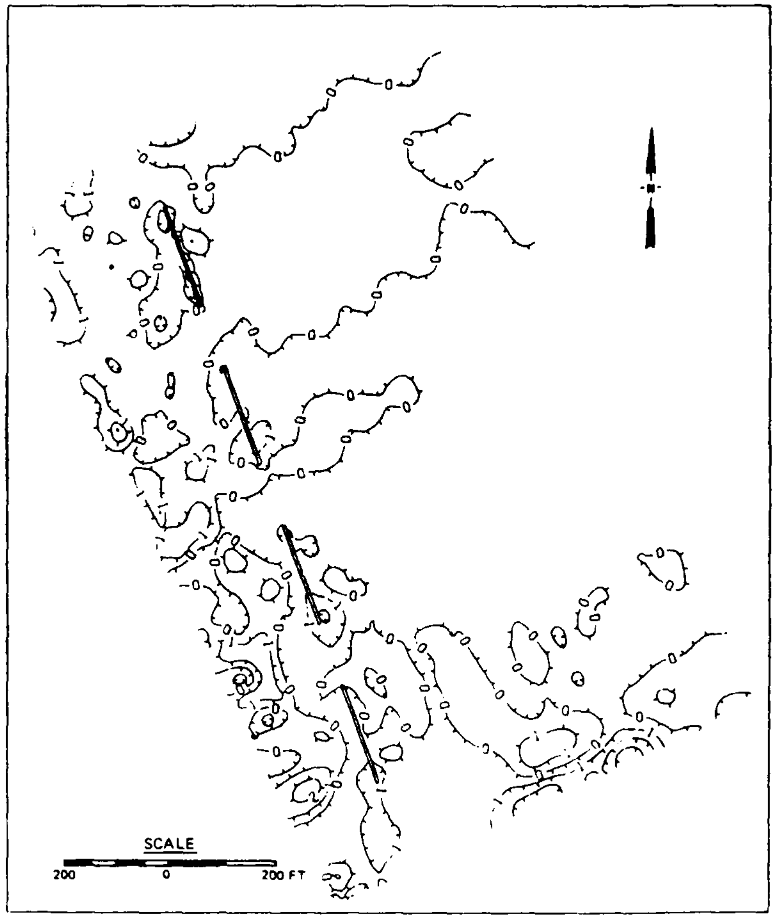

Figure 17. Central Beach November 1983 to March 1984 difference plot (in feet)

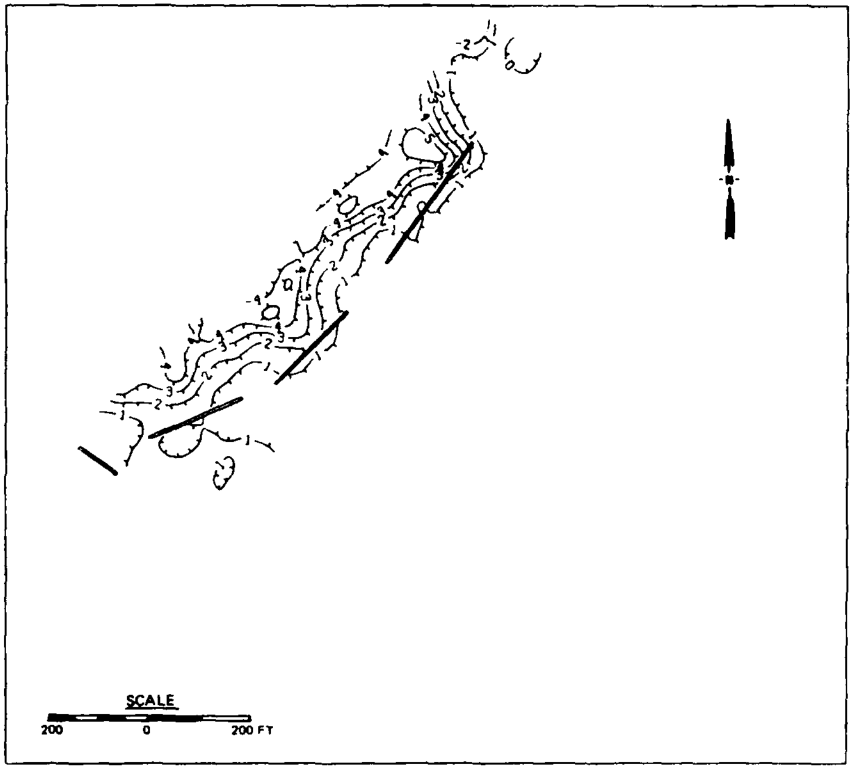

Figure 18. Castlewood Park Beach February 1981 to November 1983 difference plot (in feet)

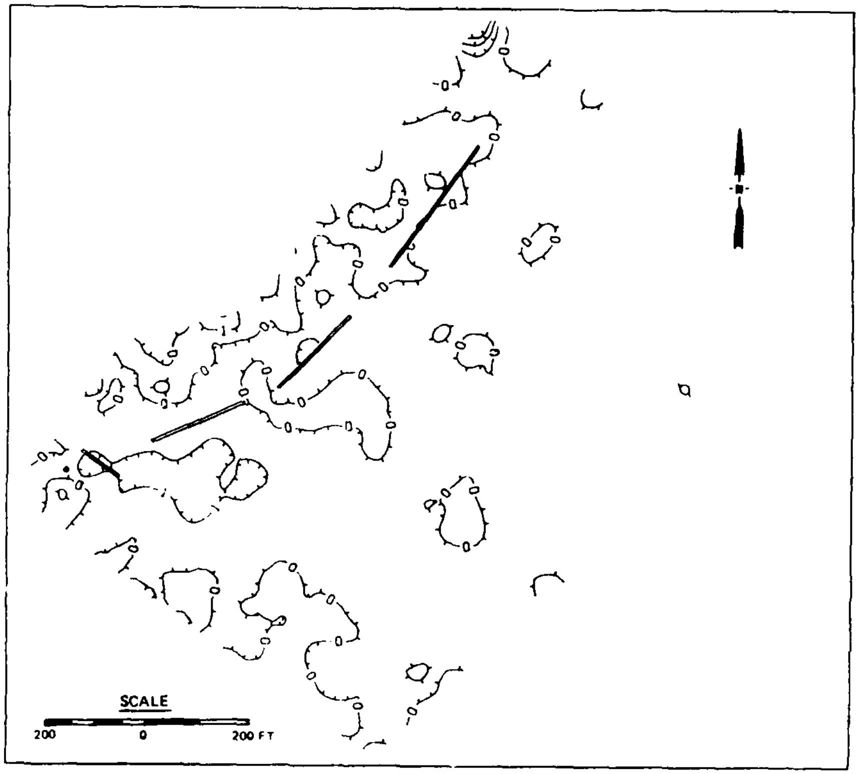

Figure 19. Castlewood Park Beach November 1983 to March 1984 difference plot (in feet)

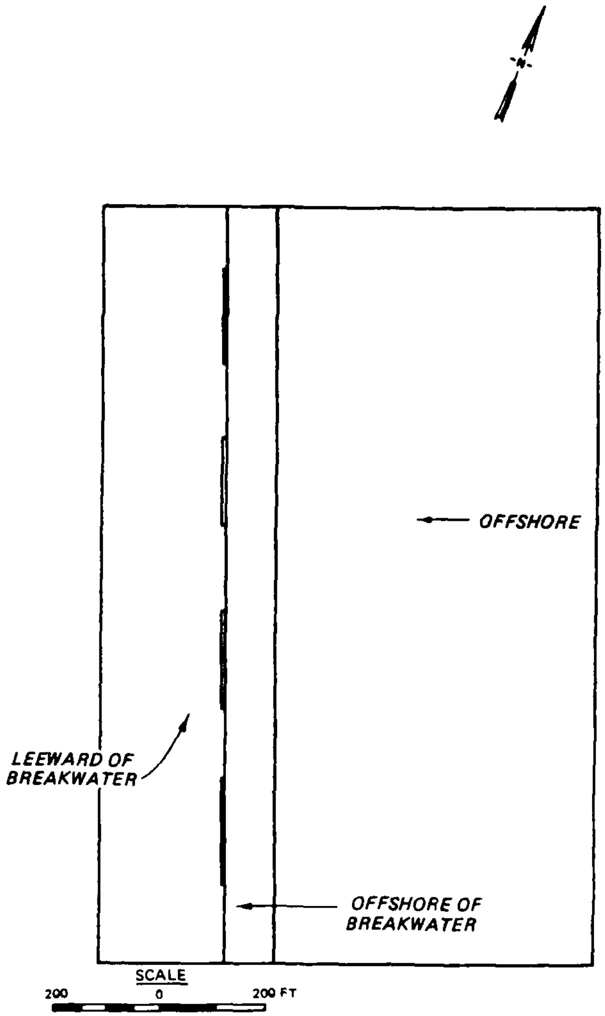

Figure 20. Central Beach regions used for volume per unit area calculations

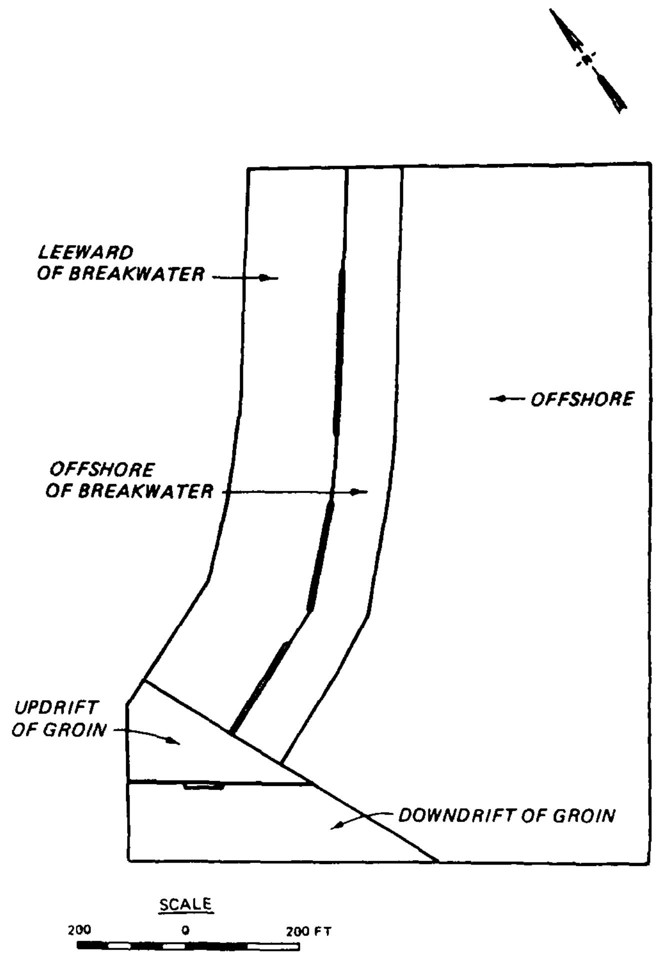

Figure 21. Castlewood Park Beach regions used for volume per unit area calculations

Table 1

Volume Changes (cu yd) for Each Site

Site/Region*	Feb 81 - Nov 83**	Nov 83 - Mar 84	Net Change**
	Central Beach		
Leeward of breakwater	56,600	-2,300	54,300
Offshore of breakwater	4,700	-1,400	3,300
Offshore	No data	-6,500	?-6,500†
Total	61,300	-10,200	51,100
	Castlewood Park Beach		
Leeward of breakwater	17,500	20	17,520
Offshore of breakwater	3,700	2,100	5,800
Offshore	No data	7,100	?+7,100
Downdrift of groin	No data	1,000	?+1,000
Total	21,200	10,220	31,420

* Regions defined in Figures 20 and 21.
** Includes quantity of fill placed October 1982.
† ? indicates no data.

Table 2

Volume Changes (cu ft/sq ft) for Each Region

	Volume Change per Unit Area		
Site/Region*	Feb 81 - Nov 83**	Nov 83 - Mar 84	Feb 81 - Mar 84**
	Central Beach		
Leeward of breakwater	3.72	-0.156	3.564
Offshore of breakwater	0.630	-0.211	0.419
Offshore	No data	-0.174	?-0.174†
	Castlewood Park Beach		
Leeward of breakwater	1.94	0.054	1.994
Offshore of breakwater	0.500	0.296	0.796
Offshore	No data	0.230	?+0.230
Downdrift of groin	No data	0.194	?+0.194

* Regions defined in Figures 20 and 21.
** Includes quantity of fill placed in October 1982.
† ? indicates no data.

PART V: DISCUSSION

31. The Colonial Beach project areas have functioned successfully, with the Central Beach "lee of breakwater" region retaining 97 percent of the fill originally placed, and the Castlewood Park "lee of breakwater" region doubling the original quantity of fill. The shoaling rate in Monroe Creek Navigation Channel has been reduced somewhat, as the dredging event scheduled for 1987 was not required. However, fluvial and tidal processes probably dominate the deposition of material in Monroe Creek channel. Dredging of the channel is expected in 1988.*

32. The original design of the Central Beach project was successful in retaining a placed fill; however, during inundations from high river flows and storm conditions, the project did not protect the bluff. In addition, standing water was occasionally present on the back beaches of both project areas, reducing usable recreational beach area. The additional material raised the beach from +3 to +4 ft mlw at Central Beach, eliminating ponding and erosion of the bluff. Volumetric analysis indicated that although Central Beach lost material from November 1983 to March 1984, the "lee of breakwaters" region lost the least volume per unit area.

33. The degree to which a segmented detached breakwater protects the beach is dependent upon the length of segment, gap distance, segment distance offshore, structure cross-sectional design, and incident wave conditions. Obviously, longer segments, shorter gap distances, structures close to shore, and impermeable cross sections will provide more protection to a beach area. Because of the relationship between the length of the breakwater segments, gap width, and wave energy at Castlewood Park Beach, a marshy tidal flat and vegetated-beach area have developed, making the site unaesthetic for recreational use. Table 3 presents a comparison of the Castlewood Park segment length to gap-width ratio with other detached-breakwater projects as presented by Pope and Dean (1987).

34. Castlewood Park Beach has the largest average segment length-to-gap-distance ratio L_s/L_g, and the smallest distance offshore relative to structure depth ratio X/d_s, indicating that this project provides the most protection of the five projects listed. The extra protection provided to the

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* Personal Communication, 1988, Edward Fulford, USAED, Baltimore, Baltimore, Maryland.

Table 3

Comparison of Various Breakwater Parameters*

Project Name	Length of Segments Ls, ft	Length of Gaps Lg, ft	Effective Distance Offshore X, ft	Depth at Structure ds, ft	Averages Ls/Lg	X/ds
Presque Isle (average water level)	125	200;300	70;100	4.8	0.5	17.7
Lakeview Park	203	160	280	12.5	1.3	22.4
Lakeshore Park	125	200	330	3.5	0.6	94.3
Central Beach	200	150	66	5.5	1.3	12.0
Castlewood Park Beach	300;200	150;90	66	5.5	2.1	12.0

* Table adapted from Pope and Dean (1987).

project area by the long segments and small gap widths reduces the response of the project to coastal processes. Littoral material transported to the south cannot enter the protected region behind the structures because of the double-ridged tombolo in the lee of the northernmost segment; the volume change data indicate that this material probably is deflected offshore. However, the project does serve the purpose of protecting the bluff and road.

35. The Central Beach structure parameters (segment length, gap distance, and distance offshore) combine to encourage water-level setup in the embayments between segments during storms. This water level setup tends to create overwash depressions on the salients/tombolos. Comparison of the Central Beach dimensionless breakwater parameters with other projects presented in Table 3 indicates that the Central Beach segments also provide more protection than the other projects listed. Segments slightly further offshore would still protect the beach, yet reduce the storm-induced water level setup in the embayments and allow longshore transport of material to continue in the lee of the structures. However, the Central Beach project is successfully protecting the bluff and road, while providing an attractive recreational area.

PART VI: SUMMARY

36. The Colonial Beach segmented detached breakwater and beach fill projects were designed by USAED, Baltimore, and built in October 1982 to protect the backshore bluff and road, create recreational areas, and reduce shoaling in the Federal Navigation Channel south of the project areas. A cooperative monitoring program between USAED, Baltimore, and CERC was initiated in October 1982 to evaluate the performance of the project sites. Although the water-level increase due to storm conditions was not fully considered in the original design of the beach fill, the project sites have successfully prevented erosion of the beach bluff. Volumetric analyses indicate that the Central Beach project area lost material during the most recent time period; however, the region which lost the least amount of sediment was to the lee of the structures. The Castlewood Park Beach project area gained nearly the same amount of material that the Central Beach area lost; however, 90 percent of this gain was in the offshore region. The Central Beach project is performing successfully in retaining the original quantity of beach fill, and Castlewood Park Beach has accreted additional material. However, the Castlewood Park Beach area has limited recreational appeal due to the marshy tidal flat and vegetative growth in the area.

37. The Colonial Beach monitoring program identified the mechanism for flooding of the back beach, and provided guidance for increasing the elevation of the beach to reduce flooding. The Colonial Beach projects were evaluated through the use of two dimensionless breakwater parameters, and their performances were compared with other prototype segmented detached breakwater projects. Beach response to structures with these dimensionless values in a wave/current environment such as Colonial Beach will tend to result in tombolo/near-tombolo formation. However, both project sites are performing as designed in protecting the back beach, bluff, and road, and in preventing project-induced shoaling of the Monroe Creek Federal Navigation Channel.

REFERENCES

Dean, J. L., Pope, J., and Fulford, E. 1986. "The Use of Segmented Detached Breakwaters to Protect Cohesive Shores: Colonial Beach, VA," Proceedings, Symposium on Cohesive Shores, May 3-5, 1986, Burlington Ontario, Canada.

Hansen, M. E. "Applications of Digital Hydrographic Data for Evaluating Coastal Projects" (in preparation), Technical Report, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Pope, J., and Dean, J. L. 1987. "Development of Design Criteria for Segmented Breakwaters," Proceedings, 20th International Coastal Engineering Conference, American Society of Civil Engineers, November 9-14, 1986, pp 2144-2158.

Toyoshima, O. 1972. Coastal Engineering for Practicing Engineers - Beach Erosion, Morikita Publishing Co., Tokyo, Japan. (English translation available for Chapter 8 on "Offshore Breakwaters," pp 227-317, through the Coastal Engineering Research Center, US Army Engineer Waterways Experiment Station, Vicksburg, MS.)

US Army Engineer District, Baltimore. 1980. "Colonial Beach, VA, Detailed Project Report," Baltimore, MD.